	Ohio Department of Transportation **Division of Planning** **Office of Geotechnical Engineering** **Geotechnical Bulletin**	**GB1**

PLAN SUBGRADES

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Geotechnical Bulletin GB1 was jointly developed by the Offices of Construction Administration and Geotechnical Engineering. It was originally issued under the title of "Interim Guidelines for Plan Subgrade Treatments," dated November 1, 2001.

This Geotechnical Bulletin is to be used for all projects that include new construction or new pavement construction after pavement removal, pavement widening, or Rubblize and Roll. Such projects have had a recent history of significant extra work change orders due to the need for subgrade stabilization, costing the Department millions of dollars.

The Designer, based on the subsurface investigation, is responsible for identifying the method, location, and dimension (including depth) of subgrade stabilization in the plans. When the stabilization or a mixture of stabilization options will be used in spot locations, the limits of the stabilization areas should be established by the Designer, by analyzing the data from the individual borings.

Appropriate stabilization of the subgrade, if necessary, will assure a constructable pavement buildup, enhance pavement performance over its life, and help reduce costly extra work change orders. The information contained in this bulletin is based on several past and recent projects and should be used as general guidance. This bulletin is simplified so the Designer can easily apply the information from the subsurface investigation to provide reasonable limits and quantities for subgrade stabilization in the plans. These limits and quantities must be verified and adjusted, as necessary, in the field based on proof rolling and visual observation.

This bulletin and other information may be obtained from the Office of Construction Administration's Web site (www.dot.state.oh.us/construction/oca/) and the Office of Geotechnical Engineering's Web site (www.dot.state.oh.us/geotechnical/). These Web sites contain details about earthwork procedures and have online copies of the Construction Inspection Manual and Geotechnical Engineering Design Checklists.

A. Subsurface Investigation

All projects covered in this bulletin shall have a subsurface investigation performed. Based on the knowledge gained on recent projects, there are no exceptions to this requirement. The subsurface investigation must be performed according to the current version of the Specifications for Subsurface Investigation, with the following adjustments for subgrades:

1. Borings

    a. Drill at offsets that will give representative samples of the subgrade to be encountered during construction, even if that means drilling through the existing pavement.

        i. If the project involves replacing or rubblizing the existing pavement, 100 percent of the borings should be drilled through the existing pavement.

        ii. If the project involves adding a lane, along with replacing or rubblizing the existing pavement, 50 percent of the borings should be drilled through the existing pavement and 50 percent of the borings should be drilled in the planned widened area.

    b. Take a 10-foot boring for new construction and a 5-foot boring for rehabilitation and widening projects (assuming the vertical alignment is not going to be changed).

    c. Perform continuous standard penetration test (SPT) sampling in the top 5 feet of the proposed subgrade.

2. Laboratory Testing

    a. Visual soil classification and moisture content must be performed on each sample.

    b. Mechanical soil classification (Plastic Limit (PL), Liquid Limit (LL), and gradation testing) shall be performed on at least two samples within 5.0 feet of the proposed subgrade from each boring. Calculate the Plasticity Index (PI) by subtracting the PL from the LL.

Old soil borings for the project should not be relied upon, due to a lack of information about the original construction cut and fill and because of moisture changes that occur beneath existing pavements. New soil boring costs are insignificant in comparison to the extra work stabilization costs.

B. Moisture Content

Comparing the existing moisture content of the soil to the optimum moisture content is an indicator for the need for subgrade stabilization. An estimated optimum moisture content for each soil classification is listed in GB1 Table A below. Some estimated optimum moisture contents are based on the PL of the sample. Where the optimum moisture content is calculated, a minimum optimum moisture content has been established.

GB1 Table A – Optimum Moisture Content

Soil Classification	Moisture Content	
	Optimum	Minimum Optimum
A-1	6	
A-3	8	
A-2	10	
A-4a	PL - 5	10
A-4b	PL - 5	10
A-6a	PL - 5	14
A-6b	PL - 5	16
A-7-6	PL - 3	18
Non-Plastic Silt	11	

Functioning drainage can reduce the subgrade soil moisture contents from plus 3 percent of optimum to optimum in six to eight weeks. Moisture contents that exceed the optimum moisture content by more than 3 percent will likely require some form of subgrade stabilization. Therefore:

1. For new construction projects, installation of construction underdrains as soon as possible is very important.

2. For rehabilitation projects, the District should inspect and reestablish drainage as necessary as soon as possible and maintain this drainage until the project is sold. This will improve the subgrade soil conditions. The Contractor should maintain the drainage during the project. As a minimum, reestablishing drainage should include cleaning all of the underdrain outlets.

3. Consider installing new underdrains systems in advance of or at the start of construction or rehabilitation projects.

C. Standard Penetration Test (SPT)

The standard penetration test (SPT) measures the number of blows per foot (N) required to drive the sampler through the soil and is an indicator of its consistency. The data is presented as the number of blows to drive each 6-inch increment, with the first 6 inches of the run ignored because the sampler may not be seated in the borehole or may be driven through cuttings. So, for example, SPT data shown as 1/2/3 would have an N value of 5 blows per foot.

When investigating the need for stabilization, the project can be evaluated as a whole or divided into segments. Divide the project into segments if there are areas that have significantly lower or higher N values. To investigate the need for stabilization for a project or segments of a project:

1. Use the lowest N (N_L) value for averaging when multiple N values are taken in the top 5 feet of subgrade.

2. When the N_L value for a boring is greater than 30 blows per foot, use 30 for calculating the average.

3. To decide the stabilization option and depth use the average N_L value derived from the boring or borings representing the area to be stabilized.

Where subgrade requiring stabilization is positively identified, subgrade stabilization should be designated in the plans for those areas.

Do not use the Rubblize and Roll rehabilitation technique when the average N_L value is below 15.

D. Designing Subgrade Stabilization

Currently the Department uses three options for establishing a stable subgrade, undercutting, cement stabilization, and lime stabilization. GB1 Table B can be used to select the stabilization option and estimate the depth. More information on each option can be obtained on the following pages of this bulletin and in the appropriate specification. The table assumes uniform soil conditions at the bottom of the stabilization.

GB1 Table B – Subgrade Stabilization

Average N_L	Undercut Option		Chemical Option	
	Depth (feet)	**703.16.C Granular Replacement** *	**Depth** (inches)	**Chemical**
0 to 5	3 to 5	Type B, C, or D	Not an Option	
5 to 10	1 to 3	Type B, C, or D	16	Cement
10 to 15	1	Type B or C	12	Cement or Lime
15 to 20	0.5	Type B or C **	9	Cement or Lime

* Always use a 712.09 Geotextile Fabric Type D with the Undercut Option.
** Item 304 may be used in lieu of the granular replacement.

Mobilizing equipment to chemically stabilize several small areas on a project can be costly. So for spot repairs the Undercut Option is likely cheaper than the Chemical Option.

If it is determined that 30 percent or more of the subgrade area must be stabilized, consideration should be given to stabilizing the entire project.

1. This consideration should include a cost analysis of the options, keeping in mind possible change orders based on additional problem areas discovered by the proof roller.

2. If the entire project is stabilized, the Chemical Option is usually cheaper.

3. If the entire project is stabilized, the Undercut Option should be used for projects with an Average N_L of 0 to 5 blows per foot or for projects with subgrade material that needs to be completely removed because of drainage, environmental, or other factors.

E. Proof Rolling (Item 204)

According to Item 204, the top 12 inches of the subgrade is compacted and the subgrade is proof rolled.

An estimated quantity for Item 204 Proof Rolling should be determined as one hour per 2000 square yards of subgrade area for reconstruction. For new construction, the quantity should be estimated at one hour per 3000 square yards.

If the Undercut Option is designed in spot locations, then specify proof rolling to identify these areas and then afterwards to verify the undercut stability.

If the Chemical Option is designated in spot locations, a quantity for Test Rolling (Item 206 or Supplemental Specification 804) should be provided to find areas that need chemically stabilized or some other form of stabilization. Test rolling is used to locate soft areas that will need to be stabilized and is done with a grader for Lime Stabilized Subgrade and a proof roller for Cement Stabilized Subgrade. Item 204 Proof Rolling should be provided to verify the stabilization. Test Rolling should be estimated at one hour per 2000 square yards of subgrade area for reconstruction and at one hour per 3000 square yards of subgrade area for new construction.

The proof rolling deflections and soil conditions that are observed during construction will determine if there is a need to adjust the plan subgrade stabilization. **Adjustment of subgrade stabilization to fit field conditions is essential and is the responsibility of the Project Engineer.** Project Engineers should refer to the Office of Construction Administration's Construction Inspection Manual.

F. Undercutting and Replacement (Item 204)

Estimate the depth of the undercut using GB1 Table B. Actual depths will be determined by the Project Engineer in the field based on the proof rolling.

Always drain the undercut to an underdrain, catch basin, or pipe.

Always use 712.09 Geotextile Fabric Type D in the bottom of the undercut. The cost is around $1.00 per square yard. In the case of deeper undercuts, multiple layers can be used, if needed, at a minimum 12-inch vertical spacing.

Replacement material will be 703.16.C Granular Material:

1. Types B, C, D, and E are much cheaper than 304.

2. Types B, C, and D are all well-graded materials. Type B has a top size of 2 inches. Type C has a top size of 3 inches. Type D has a top size of 8 inches. The larger top size material will bridge soft subgrade better than the smaller material.

3. Use Type D or E when water levels are high and cannot be drained. Always choke the Type D or E with Type B or geotextile.

4. Underdrains cannot be placed through Types C, D, or E, or the geotextile, without great difficulty. Use Type B in the areas of the underdrains. This can be accomplished by specifying the option of Type B along with Type C or D.

G. Lime Stabilized Subgrade (Item 206)

Lime Stabilized Subgrade can be used to stabilize unstable subgrades consisting of A-6b or A-7-6 soils which have a PI of 20 or greater. Lime generally is not effective in stabilizing subgrade soils with N less than 10 because the soils do not gain sufficient strength. Lime stabilize subgrade as follows:

1. For soils with Average N_L values in the range of 10 to 15, lime stabilize 12 inches of the subgrade.

2. For soils with Average N_L values greater than 15, lime stabilize 9 inches of the subgrade.

To estimate the quantity of lime, use 5 percent lime by dry weight of the soil assuming a dry weight of 110 pounds per cubic foot. No separate payment is made for water when the dry method is specified. The following formula will calculate the pounds of lime needed per square yard:

$$L = 0.0075 \times T \times D \times P$$

where:
- L = amount of lime (pounds / square yard)
- T = thickness of lime treatment (inches)
- D = average density of the soil (pounds / cubic foot)
- P = percent lime

Provide a lump sum for Item 206 Contractor Designed Lime Soil.

For curing, provide Item 408 Prime Coat estimated at 0.3 gallons per square yard. Currently, prime coat for lime stabilization is limited to 702.04 RS-1 or RS-2.

H. Cement Stabilized Subgrade (Supplemental Specification 804)

Cement Stabilized Subgrade can be used to stabilize unstable subgrades consisting of A-3, A-2, A-4a, A-6a, A-6b, or A-7-6 which have a PI less than 20. Cement generally is not effective in stabilizing subgrade soils with N values less than 5 because the soils do not gain sufficient strength. Cement stabilize subgrade as follows:

1. For soils with Average N_L values in the range of 5 to 10, cement stabilize 16 inches of the subgrade.

2. For soils with Average N_L values in the range of 10 to 15, cement stabilize 12 inches of the subgrade.

3. For soils with Average N_L values greater than 15, cement stabilize 9 inches of the subgrade.

To estimate the quantity of cement, use 6 percent cement by dry weight of the soil assuming a dry weight of 110 pounds per cubic foot. No separate payment is made for water. The following formula will calculate the pounds of cement needed per square yard:

$$C = 0.0075 \times T \times D \times P$$

where:
- C = amount of cement (pounds / square yard)
- T = thickness of cement treatment (inches)
- D = average density of the soil (pounds / cubic foot)
- P = percent cement

Provide a lump sum for Item 804 Contractor Designed Cement Soil.

For curing, provide Item 408 Prime Coat estimated at 0.3 gallons per square yard. Currently, prime coat for cement stabilization is limited to 702.04 RS-1 or RS-2.

I. Unsuitable Soils

1. **A-4b Soil**: When A-4b soil is encountered in natural ground or an existing embankment within 24 inches of top of subgrade, regardless of its consistency or moisture content, it shall be removed because of its susceptibility to frost heaving. When constructing an embankment, the use of A-4b soils within 3 feet of top of subgrade is prohibited per 203.03.

   For the Chemical Option, if the subgrade is going to be stabilized, A-4b soil may not have to be removed.

2. **A-2-5, A-5, A-7-5 Soil**: According to 703.16.A and B, A-2-5, A-5, and A-7-5 shall not be used in a subgrade.

   a. A-2-5 soil is unsuitable because of its low weight, high optimum moisture, high LL and low PI and its propensity to sloughing in service.

   b. A-5 soil is highly elastic as indicated by the high LL. It is unsuitable for a subgrade because of this elasticity.

   c. A-7-5 soil has a lower PI in relation to the LL than other clays, may be highly elastic, and subject to considerable volume change. It is unsuitable for a subgrade because of this elasticity and potential volume change.

   For the Chemical Option, if the majority or the entire subgrade is being stabilized, the Office of Geotechnical Engineering should be consulted. They will analyze the project and determine if it is possible to incorporate the A-2-5, A-5, or A-7-5 into the chemical stabilization.

3. **Liquid Limit (LL) > 65**: According to 703.16.A, when a soil sample has a LL greater than 65, it shall not be used in the subgrade. When LL is greater than 65 it indicates a soil of high clay content and low load-carrying capacity.

   For the Chemical Option, if the majority or the entire subgrade is being stabilized, the Office of Geotechnical Engineering should be consulted. They will analyze the project and determine if it is possible to incorporate the soil into the chemical stabilization. Pozzolanic reaction reduces plasticity, reduces swell, and improves strength among clay fines.

J. Rock, Shale, or Coal

When rock, shale, or coal is encountered within 24 inches of the bottom of the asphalt or concrete pavement, they are removed according to 204.05.

Replacing an existing pavement with a thicker pavement build-up can necessitate undercutting of rock, which is difficult and expensive especially in confined work areas. Designers should try to adjust the pavement design and roadway profile to avoid undercutting of rock as much as possible.